Gender Differences in Spatial Abilities: A Meta-Analysis

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Abstract

The purpose of this study is to summarize past research concerning gender differences in spatial abilities through the use of a detailed meta-analysis. Many investigators have claimed that there is a significant gender difference in spatial abilities which favors males; however, no study to date has established what is the nature and magnitude of gender differences in spatial abilities across all of the domains that encompass spatial ability. Over 676 articles were reviewed for inclusion within the meta-analysis. Seventy-three articles were considered for statistical analysis after considering the inclusion criteria. The results indicate that males demonstrate greater spatial abilities than females across all of the domains that comprise the ability. Finally, I review the impact of these results in the context of enduring educational and occupational issues regarding gender.

Key Words: Gender Differences, Sex Differences, Spatial Abilities

Introduction

In this paper I define the term spatial ability and then briefly review the history of the construct. I also review past research concerning gender differences in spatial abilities, and I describe the subdivisions and categorizations of spatial factors. Furthermore, I present a detailed explanation of the process that was used to conduct this meta-analysis and then review the results and discuss the findings. I conclude the paper with a review of the impact of these results in the context of educational and occupational issues concerning gender.

Defining Spatial Ability

The concept of "spatial ability" is not easily defined. Generally spatial abilities entail visual problems or tasks that require individuals to estimate, predict, or judge the relationships among figures or objects in different contexts (Elliot & Smith, 1983). More specifically, spatial abilities have to do with individuals' abilities to search the visual field, apprehend forms, shapes, and positions of objects as visually perceived, form mental representations of those forms, shapes, and positions, and manipulate such representations mentally (Carroll, 1993).

A Historical Review of Spatial Abilities

The history of research concerning spatial ability can be broken into three general phases of research activity. Eliot and Smith (1983) described these phases in terms of efforts in defining spatial ability:

> In the first phase (1904-1938), researchers investigated the evidence for and against the existence of a spatial factor over and above a general factor of intelligence. In the second phase (1938-1961), they attempted to ascertain the

> extent to which spatial factors differed from one another. And in the recent phase (1961-1982), researchers have attempted to designate the status of spatial abilities within the complex interrelationship of other abilities and to examine a number of sources of variance with affect performance on spatial tests (Elliot & Smith, 1983, p.1).

The basic phase structure was developed by Elliot and Smith to provide a historical review of the critical theoretical and empirical papers that have helped to define and elaborate the concept of spatial ability, while also describing the long-term impacts of defining spatial ability.

Evidence For and Against Spatial Ability (1904-1938)

In 1904, Charles Spearman published an influential report regarding a two-factor theory of intelligence. Spearman noticed that childrens' grades across seemingly distinct subjects were positively correlated and proposed that these correlations suggested the influence of a central factor, which he referred to as "g" for general intelligence. He claimed that the theory was able to account for all variations in intelligence through the use of multiple factors. The first factor, "g" represented a universal ability that directed performance on all cognitive tasks. In addition, "s" factor represented specific abilities that were assumed to be associated with each individual test.

After the publication of Spearman's two-factor theory of intelligence, many researchers worked to identify group factors which would be inconsistent with Spearman's "s" factors. One factor of interest was spatial ability. Researchers focused on providing evidence for and against the existence of a common spatial factor in addition to the general factor of intelligence (Elliot & Smith, 1983).

Stoy, E.G. (1927)

One of the earliest studies of spatial ability was reported by E. G. Stoy (1927). Stoy was concerned with finding tests which would differentiate between individuals with and without an aptitude for mechanical drawing. The participants consisted of high school freshmen who were taking their second semester of mechanical drawing. Participants were selected by their teachers based on promise or lack of promise in mechanical drawing. A total of 31 promising and 28 unpromising students participated in the experiment. Stoy administered a total of 13 separate aptitude tests concerned with spatial relations, motility, and mechanical ingenuity. Of the13 tests, six showed significant group differences between the promising and unpromising students. The six tests, which Stoy believes to be useful in mechanical drawing aptitude testing, included Thurstone-Jones Problem 4 (Paper Folding), Minnesota Paper Form Board, Downey Group Test V (Coordination of Impulses), Downey Group Test III (Flexibility), Painted Cube test, and Freeman Puzzle Box (Stoy, 1927). From the results of this experiment, it was Stoy's hope to develop enough useful tests to make a comprehensive study of aptitude for drafting.

Anderson, L.D. (1928)

In his 1928 report, L. Dewey Anderson described three mechanical ability tests that were developed at the University of Minnesota by a research organization subsidized by the Committee on Human Migration of the National Research Council. Each test was created in reaction to the unsuitable tests used in company placement programs despite the fact that the tests displayed low reliability and unproven validity.

The first test Anderson described was The Minnesota Assembly Test, which is a modified version of the original Stenquit Assembly Test. The Stenquit Assembly Test was developed in 1914 as a test for mechanical ability; however, since it did not exhibit reliability or consistency, it was revised into The Minnesota Assembly Test. The newer version of the test consisted of a number of mechanical devices that were disassembled; the participants were then instructed to assemble the parts of each device, and the accuracy with which this was done provided an index of mechanical ability. The original Stenquit test contained only ten items; however, to make The Minnesota Assembly Test more reliable an additional 24 items were added to the original ten. Another modification made to the test was the method of administration. The original test set a time limit for completion of the whole test; however, the new version set time limits for each item within a series.

The second test Anderson described was The Paper Form Board Test. The basis of this test was developed by the Army Group Examination Beta, Form O and consisted of items where there is a large figure and two or more smaller ones, which are segments of the larger one. The participant indicated by drawing lines in the large figure how the smaller ones could be fitted into it (Anderson, 1928).

Finally, the last test Anderson described was The Spatial Relations Test. This test was based on the form board test created by Dr. H.C. Link. It included two cut-out boards and one set of blocks. The blocks were placed on one board by the experimenter and then turned over on a table so that the blocks would fall out. The participant then tried to place the blocks in the same order as the experimenter had on a second board. This test was not long enough to provide a high sense of reliability, so in the newer version two pairs of boards were made, each containing 54 cut outs (Anderson, 1928). Another modification made to the test was to use boards that contained no back base so that when the board was lifted the blocks fell onto the table without being inverted.

Anderson's purpose in describing these three tests, which were high in reliability and validity, was to inform industrial psychologists of the advantages in using these reliable means of measuring mechanical ability.

Murphy, L.W. (1936)

An important study conducted by L.W. Murphy (1936) looked at the relationship between mechanical ability tests and both verbal and non-verbal intelligence tests. Some researchers believed that there did not exist a factor of mechanical aptitude distinct from general intelligence, while others believed that these are two different traits. This difference in belief led investigators to use the same tests to measure mechanical aptitude and intelligence in hopes of eradicating the difference in opinion.

In Murphy's investigation of relationship between tests of mechanical aptitude and verbal and non-verbal intelligence, 143 ninth grade boys were used as participants. Each was given 18 tests: six verbal intelligence tests, six non-verbal intelligence tests, and six mechanical aptitude tests. By using the Pearson Product-Moment formula intercorrelations between tests were found, and the resulting correlational matrix was factored by Thurston's centroid method (Murphy, 1936).

As a result of this study, many conclusions were derived, with the most important being that the verbal intelligence tests used in this study were measuring a trait different from that measured by the mechanical aptitude tests. Another important conclusion made as a result of this study was that the non-verbal intelligence test was measuring the same trait that the mechanical aptitude tests were measuring, instead of the trait that the verbal tests were measuring. In conclusion, Murphy's study was instrumental in separating mechanical ability and intelligence factors.

Thurstone, L.L. (1938)

In 1938, L.L. Thurstone developed a new theory concerning the makeup of abilities and intelligence. Contrary to Spearman's theory, Thurstone proposed that human intelligence consisted of many individual or primary factors instead of one general ability factor. In his study, Thurstone gave 56 paper-and-pencil tests to 218 college students and used his multiple-factor method that made it possible for him to discover the number of factors present in a matrix of correlations among the tests. Among the nine primary mental factors that he was able to extract, the factor that he referred to as "space" he defined as, "requiring a facility in spatial or visual imagery" (Thurstone, 1938). Thurstone classified a total of 19 tests as loaded on this factor and noted these tests all shared the distinguishing characteristics of "holding a mental image and either mentally twisting, turning, or rotating it to a different position and then matching this transformed image with a suggested solution" (Thurstone, 1938). The most important argument and finding from Thurstone's 1938 study was the claim that intelligence is better described and measured by considering distinct primary mental abilities, rather than describing intelligence as a single factor, which does not provide explicit information about specific intelligence.

Differentiating Between Spatial Factors (1938-1961)

Thurstone's revolutionary 1938 study influenced all future research based on spatial abilities. Since then, researchers no longer worked to identify a spatial factor but instead worked to establish the degree to which spatial factors differed from one another.

Woodrow, H. (1939)

One of the earliest studies conducted that used Thurstone's Primary Mental Abilities (PMA) report to select tests of spatial ability was preformed by Herbert Woodrow in 1939. Woodrow administered a total of 52 tests, which included measures of social intelligence, attention tests, temporal discrimination tests, and musical ability tests, to 110 freshman and sophomore students. Woodrow factored the resulting correlational matrix using Thurston's centroid method. The most important factors appeared to relate to verbal facility, spatial ability, numerical ability, attention, musical ability, and memory span. Another important aspect of Woodrow's conclusions from this study was his identification of male superiority in tests of spatial abilities.

Guilford & Lacey (1947)

A new measure for quickly screening abilities for large numbers of military personnel was desperately needed once World War II began. The military needed a way to classify and group individuals based on their abilities, especially for those who were capable of becoming a pilot. In 1947, Guilford and Lacey reported the results of the Army Air Forces (AAF) factor analytic studies which provided solid evidence for the existence of two strong spatial factors called Spatial Relations (Sr) and Visualization (Vz). Tests that loaded on the Spatial Relations factor included Thurstone's Flags, Figures, Cards, and Cubes and were thus thought to be the same as the factor Thurstone referred to as “space” (Thurstone, 1938). Guilford and Lacey reported that the Spatial Relations factor “seems to involve relating different stimuli to different responses, either stimuli or responses being arranged in spatial order” (1947). The Visualization factor was defined by the Space Visualization I test, which involves a paper folding task and other similar tests. Guilford and Lacey felt that the Visualization factor was strongest in tests that present a stimulus either pictorially or verbally, and in which some manipulation or transformation to another visual arrangement is involved (1947). Guilford and Lacey also reported on two tentative space factors, S2 and S3; however, their existence is not strong or significant enough to be mentioned further.

Michael, Zimmerman, and Guilford (1951)

Michael et al. (1951) conducted a study which administered a total of seven spatial ability tests and eight reference tests to 151 male and 139 female participants ranging in age from 15 to 20. Separate analyses were performed for each group, and both groups produced six identifiable factors: Visualization, Spatial Relation, Number, Verbal, Perceptual Speed, and Reasoning. Michael et al. concluded that “the factor pattern in each test was approximately the same for the two groups” (1951, p. 561). However, Michael et al. also concluded that sex differences in spatial ability were found. The results indicated that males outperformed females on most of the spatial abilities.

Zimmerman, (1954)

In 1954 Zimmerman carried out a study that sought to determine the comparative factor structure of three forms of the AAF experiment through the use of factor analysis. Zimmerman’s study established that by increasing the difficulty of items on an AAF test, a test could be formed to stress a perceptual speed factor, a space factor, and a visualization factor. In his experiment, Zimmerman used the *Visualization of Maneuvers* test and increased the difficulty of the test throughout the experiment. The easiest experiment required participants to choose which picture correctly represented an airplane's position after it had performed a specific maneuver. The test of medium difficulty required the participant to complete the same procedure after imagining the plane completing two given maneuvers, and the most difficult test required the participant to choose after the plane had completed three maneuvers. Zimmerman claimed that, "The easier form had the highest loading on perceptual speed. . . the test of medium difficulty led the others on space. . . and the most difficult of the three led the others with a heavy weight in Visualization" (Zimmerman, 1954, p.106). Thus, Zimmerman was able to provide some evidence for the notion of a hierarchy of spatial factors.

Correlating Spatial Abilities to Other Abilities and Finding Sources of Variance in Spatial Abilities (1961-Present)

Although the exact number of subdivisions of the spatial factor is not universally agreed upon, the most current research no longer tries to differentiate between subdivisions. In general, most researchers will agree to the notion of at least three broad and widely researched subdivisions (Visualization, Spatial Relations, and Spatial Orientation) and seven smaller, less frequently researched subdivisions (Flexibility of Closure, Closure Speed, Spatial Scanning, Perceptual Speed, Serial Integration, Visual Memory, and Kinesthetic) (Lohman, 1984). More recently, research has focused on the intercorrelations between spatial abilities and other abilities and on the different sources of variation in performance on spatial tests.

French (1965)

J.W. French (1965) investigated the relationship between problem-solving styles and cognitive processes. French was interested in how individuals' problem-solving techniques affected their performance on tests of spatial ability. French administered five "pure" factor tests and ten "factorally complex" tests to 177 male participants. Participants were interviewed while they solved test items and completed a questionnaire concerning their test taking strategies. After completing a factor analyses, French concluded that the most persistent strategy used to complete tasks was "some kind of reasoned or systematic approach as contrasted to less orderly scanning and visualizing, with reliance on common sense" (French, 1965). French also noted that "systematizing is a tendency which leads a person to use specialized or symbolic thought processes; this changes what the tests measure and, consequently, affects the correlations between the tests" (1965).Thus it was found that this systematic approach to test solving helped to decrease the correlation between verbal and spatial factors and had different effects on different tests.

Horn and Cattell (1966)

The major purpose of the Horn and Cattell (1966) study was to "illustrate the structure in a comprehensive sample of primary mental ability factors with the aim of determining whether or not this is generally consistent with the process of the theory of fluid and crystallized intelligence" (Horn and Cattell, 1966). They administered a battery of tests that represented a total of 23 primary abilities and 8 general personality dimensions to 297 participants. After completing a factor analysis, several correlations where found. One main conclusion that resulted from this study includes the notion of fluid intelligence being represented by tasks that involve "processes of perceiving relations, maintaining span of immediate awareness in reasoning, and abstracting in both speeded and unspeeded tasks of a relatively culture-fair kind but involving figural, symbolic, and semantic content" (Horn & Cattell, 1966). Another important conclusion that resulted from this study was the concept of crystallized intelligence being represented by very similar processes as fluid intelligence but also "involving tasks requiring considerable pertaining to acquire techniques representing the accumulated wisdom of a culture" (Horn & Cattell, 1966). Finally, the most pertinent conclusion relating to spatial abilities involves the concept of general visualization being represented by "processes of imagining the way objects may change as they move in space, maintaining orientation with respect to objects in space, keeping configurations in mind, finding the gestalt among disparate parts in a visual field, and maintaining a flexibility concerning other possible structuring of elements in space" (Horn & Cattel, 1966, p. 253).

Lohman(1979)

In 1979, Lohman published an extensive reanalysis of selected correlational literature and factorial studies concerning spatial ability. He selected data from a wide range of spatially related studies including Thurstone's PMA study, The Holzinger-Swineford studies, The AAF Work, Thurstone's later batteries, Guilford's postwar work, and the Structure of Intellect studies. Lohman used a variety of hierarchical factor-analytic procedures and concluded that three major and four minor spatial factors exist.

The three major factors Lohman defined included Spatial Relations, Spatial Orientation, and Visualization. He defined spatial relations as involving a task that required an object to be mentally rotated, spatial orientation as involving a task that required a stimulus to be pictured from a different perspective, and visualization as involving more complex and difficult tasks that were non-speeded in nature. Commenting on the minor spatial factors Lohman stated:

> Factors like Closure Speed, Perceptual Speed, Visual Memory, and Kinesthetic may represent individual differences in the speed or efficiency of these basic cognitive processes. However, these factors surface only when extremely similar tests are included in a test batter. Such tests and their factors consistently fall near the periphery of scaling representations, or at the bottom of a hierarchical model (Lohman, 1979, p.319).

Lohman later listed a total of ten spatial factors which included the addition of three other minor spatial factors: Flexibility of Closure, Spatial Scanning, and Serial Integration (Lohman, Pellegrino, Alderton, & Regian, 1987). I will provide a more detailed description of Lohman's ten spatial factors later in this paper.

Lansman, Donaldson, Hunt, and Yantis(1982)

More recently Lansman et al. (1982) conducted a study concerned with relations between abilities measured by paper-and-pencil methods and those measured by an experimental laboratory setting. They attempted to relate ability factors (fluid intelligence, crystallized intelligence, spatial visualization, and clerical perceptual speed) to measures of subjects' speed of information processing.

Lansman et al. administered a battery of paper-and-pencil tests designed to measure fluid intelligence, crystallized intelligence, spatial visualization, and clerical perceptual speed to 45 male and 46 female undergraduate participants. Participants also completed paper-and-pencil and computerized versions of 3 information processing tasks: mental rotations, letter matching, and sentence verification. After reviewing the results Lansman et al. concluded that "The 4 ability factors were independent in subjects. Speed of letter matching and sentence verification were correlated, but neither was related to speed of mental rotation. Mental-rotation speed was found to strongly correlated with spatial visualization, letter-matching speed was correlated with clerical perceptual speed, and sentence-verification speed was correlated with both crystallized intelligence and clerical perceptual speed" (Lansman et al., 1982).

Research Conducted Concerning Sex Differences in Spatial Abilities

One of the most widely discussed topics that is currently being researched concerning spatial ability deals with an existence, or lack of an existence, of sex differences in spatial abilities. This highly debated topic has recently gained even more attention after Lawrence Summers (the recent President of Harvard University) made claims concerning the differences between men and women and their different levels of representation, especially in the faculties of science and mathematics fields. No clear agreement on the subject matter has been reached. For example, Maccoby and Jacklin (1974) contended that gender differences in spatial ability do exist, while Caplan et al. (1985) contended that any gender differences found are too small to be significant or consequential.

Arguments for Gender Differences in Spatial Ability

Many researchers believe that substantial sex differences in spatial abilities do exist. However, researchers have not been able to claim that gender differences in spatial abilities exist across the entire range of sub-factors of spatial abilities. Instead, researchers have only been able to find sex differences in specific subdivisions of spatial ability. For example, Linn and Peterson (1985) reported a large gender difference in mental rotation tasks favoring males, and Alexander (2005) reported a gender difference in visual memory tasks favoring females. Maccoby and Jacklin (1974) also made claims of gender differences using only one sub-factor of spatial abilities. They separated the field of spatial ability into two groups: non-visual and visual spatial abilities and then used the Embedded Figures Test to suggest that visual-spatial ability tests show sex differences favoring men.

With researchers making claims of the existence of gender differences in spatial abilities, it seems only natural for other researchers to provide possible reasons for such differences. Brownlow et al. (2003) suggests that women's poor performance on mental rotation tasks may be due to the knowledge of negative social stereotypes, which suggest that women perform less well on tests of spatial ability than men do.

Crawford et al. (1995) makes similar claims in proposing that women are negatively influenced by identifying a test as a measure of their spatial ability. Specifically, when women are told that a task will be used to measure their spatial ability, their performance is worse than when they are not told anything about the purpose of the task. Crawford et al. (1995) also contend that this difference in spatial ability due to social stereotypes is evident even during childhood. They propose that the gender-specific toys that are given to children engage different types of abilities from a very young age. For example, boys are often given blocks and LEGOS from which they are able to build models and structures from pictures and diagrams. In contrast, girls are often given dolls and Barbies which they are able to nurture but not manipulate. “Boy” toys seem to help engage and develop spatial abilities while “girl” toys do not. Thus, it seems natural to link men’s superior spatial ability to the lack of female experience and familiarity with spatial tasks.

Recently, Ginn and Pickens (2005) noted that previous research suggested that the male advantage on mental rotation tasks might be related to experience with spatial tasks. The study conducted by Ginn and Pickens (2005) examined whether participation in different types of spatial activities would affect women’s performance on mental rotation tasks. Ginn and Pickens administered a mental rotation test to 31 male and 59 female participants who were either enrolled in a music or art class or who participated in athletics at a local college. Ginn and Pickens found that women’s scores on the mental rotation test were affected by their participation in spatial activities. Women who participated in music, art, or athletics had more experience with spatial activities and scored higher on the mental rotation test than did women who did not participate in these activities. It seems that practice is an important factor affecting the existence of sex differences in spatial abilities.

There is considerable evidence supporting the existence of gender differences in spatial abilities; however, researchers have only been able to make claims of sex differences in specific subdivisions of spatial ability. Moreover, many claims have been made about possible social and environmental causes of sex differences in spatial abilities.

Arguments <u>against</u> Gender Differences in Spatial Ability

While many researchers contend that substantial sex differences in spatial abilities exist, an equal number of researchers maintain that substantial gender differences in spatial abilities do not exist. Researchers who challenge the notion of sex differences argue that the current research on sex differences in spatial ability is inconsistent and flawed. The most well-known paper supporting that evidence for sex differences is unreliable was written in 1985 by Caplan, MacPherson, & Tobin. Caplan et al. (1985) suggested that part of the reason for some of the inconsistency in research findings may be due to a lack of a clear and agreed upon definition for "spatial ability." Until a universal definition for the construct of spatial ability is developed, researchers will not to able to reach a consensus concerning the existence of sex differences in spatial abilities according to the authors. Moreover, Caplan et al. (1985) claimed that experimental tests are often erroneously categorized as measures of spatial ability and then used to describe inaccurate conclusions regarding gender differences in spatial ability, when the tests are not actual measures of spatial abilities. Caplan et al. (1985) also suggested that results drawn from many studies are often over-generalized. For explain, single-test studies are used to draw overall conclusions regarding sex differences in spatial abilities.

While some researchers make claims about possible environmental causes for gender differences in spatial abilities, Lohman (1986) maintained that gender differences in spatial abilities can be eliminated with exposure and practice. Thus, he believed that if female children or adults are given ample opportunity to practice a spatial task, no gender difference will exist.

Summarizing Past Research

Since the early 1900s researchers have been interested in defining human cognitive abilities. The first phase of research activity regarding spatial ability was concerned with defining its existence as a separate ability from “g”. Once it was accepted, researchers attention was turned toward identifying and differentiating between spatial factors. Finally, research has now shifted towards understanding the different sources of variation in spatial ability performance and defining spatial abilities in terms of their correlations with other human abilities. One topic that is currently being researched concerning spatial ability deals with an existence, or lack of an existence, of sex differences in spatial abilities. Although there are many theories concerning this highly debated topic, the purpose of my research is to conduct a meta-analysis which will establish the nature and magnitude of gender differences in spatial abilities across all of the domains that encompass spatial ability.

Meta-Analysis of Gender Differences in Spatial Abilities

Method

Literature Search

Studies for possible inclusion in the meta-analysis were originally identified by searching several internet based databases. Most articles were derived from the database PsycInfo; however, Google Scholar, PsycARTICLES, and ERIC were also investigated. Searches were conducted using combinations of the terms *sex differences, gender* *differences,* and *spatial abilities,* while conjoining the terms with *in,* and *and* statements. Six-hundred and seventy-six articles were reviewed for possible inclusion; studies were excluded from the meta-analysis if : (a) participants were younger than 5 years of age, (b) participants were older than 70 years of age, (c) studies only examined male or female participants, (d) participants were visually impaired, (e) participants were drawn from clinical populations, (f) studies examined nonhuman subjects. Seventy-three studies remained after the inclusion criterion was implemented. The studies that were used in the statistical procedures of the meta-analysis are noted with an asterisk in the Reference section of this paper.

Classification and Subdivisions of Spatial Factors

The taxonomy of spatial abilities constructed by Lohman, Pelegrino, Alderton, & Regian (1987) was used throughout this thesis to classify spatial tests into spatial subdivisions. Lohman et al. proposed the existence of 10 distinct and significant subdivisions of spatial abilities; Table 1 lists these 10 major and minor spatial sub-factors while also recording tests that define the factor.

Table 1. Spatial Subdivisions

Factor Label	Factor Name	Tests that Define the Factor
Vz	Visualization	Paper Folding, Paper Form Board, Surface Development
SO	Spatial Orientation	Card Rotation, Cube Comparison, Water Level
Cf	Flexibility of Closure	Embedded Figures, Hidden Figures, Copying, Hidden Patterns
SR	Speeded Rotation	Cards, Flags, Figures
Ss	Spatial Scanning	Maze Tracing, Choosing a path, Wayfinding
Ps	Perceptual Speed	Finding A's Test, Number Comparison, Identical Pictures
SI	Serial Integration	Successive Perception, Picture Identification
Cs	Closure Speed	Gestalt Completion, Concealed Words
Vm	Visual Memory	Location Memory, Memory for Design
K	Kinesthetic	Hands

Visualization is a factor of spatial ability that requires examinees to apprehend a spatial form, shape, or scene while often at the same time rotating it in two or three dimensions one or more times. Spatial Orientation is also a factor of spatial ability, but it requires examinees to determine how an object or scene will appear when viewed from a new perspective. Flexibility of Closure is another factor of spatial ability, and it often requires examinees to break one gesalt and form another; examinees might also be asked to find a simple figure embedded in a more complex shape. The factor Speeded Rotation requires examinees to determine whether a given stimulus is a rotated version of the target or is a rotated and reflected version of the target. Spatial Scanning is a spatial factor that asks examinees to perform tasks of speed while accurately following an indicated route or path through a visual field. Perceptual Speed provides examinees with tests that require them to match visual stimuli rapidly. Serial Integration is another factor of spatial ability; it measures an examinee's ability to integrate temporally speeded visual stimuli. Closure Speed is another spatial factor which tests examinees on their ability to quickly identify an incomplete or distorted picture. Another aspect of the sub-factor, Closure Speed, is the ability to combine disconnected, vague, visual stimuli into a meaningful whole. Visual Memory is also a factor of spatial ability, but it requires the examinee to recognize a previously seen picture or geometric form. Finally, Kinesthetic is yet another factor of spatial ability; it represents the ability to make rapid left-right discriminations.

Although other researchers have made claims of other or different subdivisions of spatial factors, Lohman's 10 factors, which are described above, were used to classify all tests of spatial ability throughout this meta-analysis.

Procedure

Organization of Article Information. The first step in constructing the meta-analysis was to organize all of the statistical information provided within the reviewed articles. This was accomplished by creating a detailed spreadsheet which contained the following information for each spatial test within an article: identification of the spatial test used, classification of the spatial test (subdivision of the ability), reliability of the test, sample sizes for male participants, female participants, and total participation, sample characteristics, means and standard deviations for males and females recorded separately, and effect sizes.

Calculations for Effect Sizes. Although many articles reported effect sizes, some authors failed to provide such information. In cases where effect sizes were not reported but sample size, mean, and standard deviation were reported, I computed the effect size (Cohen's *d*) by hand using the method suggested by Hedges & Olkin (1985). First, I found the average standard deviation across the male and female groups. Next, I subtracted the mean for males by the mean for females and then divided by the average standard deviation found in step one.

The next step in the statistical process of the meta-analysis involved correcting the observed effect sizes for measurement error. This process is necessary because lower values of reliability for tests will often lead to underestimates of the effect size. To prevent this measurement error from occurring I used the formula provided by Hedges & Olkin (1985) seen below.

$$r_i^* = r_{xy} / \sqrt{(r_{xx} r_{xy})}$$

I divided each entry's effect size (r_{xy}) by the square root of the test reliability ($r_{xx} * r_{xy}$). Reliability estimates were derived from multiple sources. Articles that described the development of the scales and reported the scales test-retest reliability estimates represented the preferred method for providing reliability estimates. When no reliability reports were provided, I tried to find reliability estimates that were reported in other research studies that used the same measure. However, when I was unable to find any reliability estimates, I used the mean value of reliability estimates that had been acquired through other measures. After completing this statistical step, I added another column to my spreadsheet which contained each test's effect size corrected for measurement error.

Calculations for Weighted Mean Effect Size. To obtain mean effect sizes for each spatial factor, all of the different test data had to be grouped by categories, thus one weighted mean effect size was computed for each spatial factor. In calculating the weighted mean effect size, I used methods described by Hedges & Olkin (1985). In order to compute the weighted mean effect size, the effect size for each test, corrected for measurement error, was multiplied by the test's total sample size and then added to other tests within the spatial subdivision. This number was then divided by the sum the total sample size of all the tests. An example formula for this process is provided below.

$$\frac{\text{(Test 1: corrected effect size * total sample size) + (Test 2: corrected effect size * total sample size)}}{\text{Test 1 total sample size + Test 2 total sample size}}$$

Confidence Intervals: The technique I used for computing confidence intervals was found in Hedges and Olkin (1985) and the following formula was used:

$$Z_L = Z - (1.96 / \sqrt{(N-3k)})$$

$$Z_U = Z + (1.96 / \sqrt{(N-3k)})$$

where 1.96 was used to provide the two-tailed critical *z* value for the 95% confidence interval, *N* represents the total sample size within each subfactor groupings, and *k* denotes the number of studies within each subfactor grouping.

Overall Statistics. The last step in the statistical portion of the meta-analysis was to compute one overarching effect size across all of the individual effect sizes, then to compute an overall average effect size, and finally to provide an overall confidence interval. The same formulas, noted above, were followed to create these overall statistical values.

Results

The results of the meta-analysis are shown in Tables 2 and 3. Table 2 provides the statistical results from the meta-analysis procedure. The table provides the weighted mean effect sizes, the 95 % confidence intervals, the average effect sizes for each factor, the overall average effect size, and the overall confidence interval. The first thing to examine from this table is the overarching effect size across all of the individual effect sizes. The results indicate, by the presence of a significantly positive number that when generally speaking about the overall spatial abilities males out perform females. The next important pieces of information which should be noted within Table 2 are the average effect sizes for each spatial factor. Although all nine of the factors tested produced positive numbers, meaning that males out performed females, some of the factors tested produced a smaller gender difference in performance than others. For example, with an average effect size of 1.007, Spatial Scanning is clearly a factor of spatial ability for which males demonstrate a greater ability, on average. However, with an average effect size of 0.1753, Closure Speed is a factor where womens' abilities seem to be less differentiated from males' abilities. In other words, although males out performed females in all spatial factors, the difference between genders varies considerably.

Table 2
Statistical Results from Meta-Analysis Procedure

Spatial Ability Factor	Weighted Mean Effect Sizes	Total Number of Effect Size Estimates (K)	Total Number of Participants (N)	95% Confidence Intervals (CI)	Average Effect Size for Each Sample
Closure Speed (Cs)	0.174	3	1935	0.129 ≤ δ ≤ 0.219	0.1753
Flexibility of Closure (Fc)	0.231	6	2463	0.191 ≤ δ ≤ 0.271	0.2353
Kinesthetic (K)	0.653	1	40	0.331≤ δ ≤ 0.975	0.6527
Spatial Orientation/Spatial Relations	0.41	13	3988	0.379≤ δ ≤ 0.441	0.48094
Speeded Rotation (Sr)	0.633	26	9074	0.021≤ δ ≤ 0.654	0.66153
Spatial Scanning (Ss)	0.965	3	1375	0.912 ≤ δ ≤ 1.018	1.007
Perceptual Speed (Ps)	0.1558	3	1233	0.998 ≤ δ ≤ 0.212	0.18626
Visual Memory (Vm)	0.502	6	1079	0.442 ≤ δ ≤ 0.562	0.69861
Viszualization (vz)	0.3017	11	4062	0.271 ≤ δ ≤ 0.333	0.25264
	Overall average Effect Size	**Total Number of Effect Size Estimates (K)**	**Total Number of Participants (N)**	**Overall Confidence Interval (CI)**	
	0.5124	72	25249	**0.5 ≤ δ ≤ 0.525**	

Table 3 provides information regarding statistical data from each of the spatial tests used within the meta-analysis. This table presents the following information for each spatial test: spatial factor, reliability of test, total sample size, sample size for males, sample size for females, sample characteristics for males and females, effect sizes, and effect sizes corrected for measurement error. The purpose of providing this table is to grant an opportunity to reproduce the results found by this meta-analysis.

Table 3
Statistical Data From Spatial Tests

Author	Year	Spatial Factor	Reliability	Sample Size Total	Sample Size Male	Sample Size Female	Sample Characteristics (age: mean, standard deviation, range)	Sample Characteristics (Males)	Sample Characteristics (Females)	Effect Size	Effect Sizes corrected for measurement error
Birenbaum et al.	1994	Cs	0.71	410	204	206	M=22.7 SD=3.80	M=9.4 SD=2.8	M=9.6 SD=3.1	0.07	0.0831
Contreras et al.	2001	Cs	0.751	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.29	0.3346
Lachance & Mazzoco	2006	Cs	0.7305	923	448	475	children in longitudinal study (started in kindergarden lasted 4 years)	Kind: M=5.83 SD=0.35 1st: 6.83 SD=0.34 2nd: M=7.84 SD=0.35 3rd: M=8.73 SD=0.30	Kind: M=5.72 SD=0.33 1st: M=6.69 SD=0.30 2nd: M=7.69 SD=0.31 3rd: M=8.61 SD=0.32	0.0925	0.1082
Ecuyer-Dab & Robert	2004	Fc	0.82	216	95	121	(specific by sex)	M=34.3 SD=6.2	M=34.2 SD=6.1	0.0162	0.0179
Hegarty et al.	2006	Fc	0.82	221	83	135	M=22.0 SD=7.1 range: 17-59	n/a	n/a	0.21	0.2319
Lachance & Mazzoco	2006	Fc	0.832	923	448	475	children in longitudinal study (started in kindergarden lasted 4 years)	Kind: M=5.83 SD=0.35 1st: 6.83 SD=0.34 2nd: M=7.84 SD=0.35 3rd: M=8.73 SD=0.30	Kind: M=5.72 SD=0.33 1st: M=6.69 SD=0.30 2nd: M=7.69 SD=0.31 3rd: M=8.61 SD=0.32	0.0625	0.0685
Lachance & Mazzoco	2006	Fc	0.82	923	448	475	children in longitudinal study (started in kindergarden lasted 4 years)	Kind: M=5.83 SD=0.35 1st: 6.83 SD=0.34 2nd: M=7.84 SD=0.35 3rd: M=8.73 SD=0.30	Kind: M=5.72 SD=0.33 1st: M=6.69 SD=0.30 2nd: M=7.69 SD=0.31 3rd: M=8.61 SD=0.32	0.38	0.4196
Stericker & LaVesconte	1982	Fc	0.82	83	38	45	college aged students	n/a	n/a	0.18	0.1988
Weiss et al.	2003	Fc	0.82	97	46	51	college aged students	n/a	n/a	0.43	0.4749

Govier & Gail	2000	K	0.817	40	20	20	range:20-35	M=30.15 SD=3.30 range: 24-35	M-28.45 SD=3.48 range: 22-34	0.59	0.6527
Birenbaum et al.	1994	Ps	0.92	410	204	206	M=22.7 SD=3.80	M=38.7 SD=8.9	M=39.8 SD+9.1	-0.12	-0.1251
Contreras et al.	2001	Ps	0.751	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.21	0.2423
Hegarty et al.	2006	Ps	0.78	221	83	135	M=22.0 SD=7.1 range: 17-59	n/a	n/a	0.39	0.4416
Alexander	2005	So	0.92	120	60	60	M = 20.4+/-1.9 range: 18-35	n/a	n/a	0.7	0.7298
Amponsah	1997	So	0.84	417	288	229	M = 26.5 range: 18-40	M=1.86 SD=2.20	M=1.04 SD=1.38	0.21	0.2291
Amponsah	1997	So	0.95	417	288	229	M=26.5 range:18-40	M=5.13 SD=1.91	M=3.22 SD=2.63	0.35	0.3591
Choi & L'Hirondelle	2005	So	0.92	111	50	61	(specific by sex)	M=19.43 SD=0.15	M=19.17 SD=0.16	1.68	1.7515
Choi & Silverman	2003	So	0.92	290	144	146	range: 9-13	n/a	n/a	0.68	0.7089
Contreras et al.	2001	So	0.918	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.67	0.6993
Meehan & Overton	1986	So	0.92	84	42	42	(specific by sex)	M=20.8 SD=2.3	M=21.7 SD=2.6	-0.3667	-0.3823
Ecuyer-Dab & Robert	2004	So	0.92	216	95	121	(specific by sex)	M=34.3 SD=6.2	M=34.2 SD=6.1	0.0162	0.0169
Golbeck & Sinagra	2000	So	0.92	91	22	69	M=22.7 SD=5.47	n/a	n/a	0.23	0.2398
Hegarty et al.	2006	So	0.74	221	83	135	M=22.0 SD=7.1 range: 17-59	n/a	n/a	0.17	0.1976
Kass & Ahlers	1998	So	0.92	42	21	21	M=33.86 SD=9.46 range:21-57	n/a	n/a	0.93	0.9696
Lachance & Mazzoco	2006	So	0.92	923	448	475	children in longitudinal study (started in kindergarden lasted 4 years)	Kind: M=5.83 SD=0.35 1st: 6.83 SD=0.34 2nd: M=7.84 SD=0.35 3rd: M=8.73 SD=0.30	Kind: M=5.72 SD=0.33 1st: M=6.69 SD=0.30 2nd: M=7.69 SD=0.31 3rd: M=8.61 SD=0.32	0.14	0.1460

Nordvik & Amponsah	1998	So	0.96	tech students: 161 social science students: 293	Technology: 94 Social Science: 68	Technology: 67 Social Science: 225	(specific by sex)	Technology: M=20.3 SD=1.1 Social Science: M=22.2 SD=3.5	Technology: M=19.8 SD=0.9 Social Science: M=22.0 SD=4.7	0.575	0.5869
Alexander	2005	Sr	0.83	120	60	60	M = 20.4+/-1.9 range: 18-35	n/a	n/a	1.19	1.3062
Amponsah	1997	Sr	0.87	417	288	229	M=26.5 range:18-40	M=62.76 SD=21.15	M=54.82 SD=19.80	0.19	0.2037
Amponsah	1997	Sr	0.71	417	288	229	M=26.5 range:18-40	M=9.97 SD=6.71	M=7.54 SD=5.05	0.19	0.2255
Amponsah	1997	Sr	0.89	417	288	229	M=26.5 range:18-40	M=78.66 SD=23.33	M=67.69 SD=22.85	0.22	0.2332
Amponsah	1997	Sr	0.8	417	288	229	M=26.5 range:18-40	M=19.64 SD=8.81	M=13.87 SD=6.85	0.34	0.3801
Birenbaum et al.	1994	Sr	0.96	410	204	206	M= 22.7 SD =3.80	M=41 SD=12.4	M=35.7 SD=13.1	0.41	0.4185
Campos & Cofan	1986	Sr	0.83	100	50	50	M=16.8 range: 16-20	n/a	n/a	-0.3	-0.3293
Choi & L'Hirondelle	2005	Sr	0.83	111	50	61	(specific by sex)	M=19.43 SD=0.15	M=19.17 SD=0.16	1.68	1.8440
Choi & Silverman	2003	Sr	0.83	290	144	146	range: 9-13	n/a	n/a	0.26	0.2854
Contreras et al.	2001	Sr	0.87	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.17	0.1823
Crucian & Berenbaum	1996	Sr	0.83	218	86	132	range: 18-46	M=20.0 SD=2.6	M=20.1 SD=4.3	0.77	0.8452
Ecuyer-Dab & Robert	2004	Sr	0.83	216	95	121	(specific by sex)	M=34.3 SD=6.2	M=34.2 SD=6.1	0.0162	0.0178
Flaherty	2005	Sr	0.83	115 Ecuadorian 120 Irish Caucasian 128 Japanese	57 Ecuadorians 60 Irish 64 Japanese	58 Ecuadorians 60 Irish 64 Japanese	(specific by sex)	Ecuadorian: M=17.47 SD=2.40 Irish: M=20.43 SD=1.75 Japanese: M=20.43 SD=2.49	Ecuadorians: M=18.10 SD=3.01 Irish: M=18.76 SD=2.51 Japanese: M=20.59 SD=1.12	0.36	0.3952
Goldstein et al.	1990	Sr	0.83	70	35	35	M=18.6 SD=0.83 range: 18-22	n/a	n/a	0.85	0.9330

Hegarty et al.	2006	Sr	0.88	221	83	135	M=22.0 SD=7.1 range: 17-59	n/a	n/a	0.7	0.7462
Hooven	2004	Sr	0.7	144	70	74	M=28 SD=12 range: 18-50	n/a	n/a	0.46	0.5498
Malinoski	2001	Sr	0.83	211	142	68	college aged students	n/a	n/a	1.32	1.4489
Nordvik & Amponsah	1998	Sr	0.82	technology: 161 social science students: 293	Technology: 94 Social Science: 68	Technology: 67 Social Science: 225	(specific by sex)	Technology: M=20.3 SD=1.1 Social Science: M=22.2 SD=3.5	Technology: M=19.8 SD=0.9 Social Science: M=22.0 SD=4.7	0.636	0.7023
Nordvik & Amponsah	1998	Sr	0.89	technology : 161 social science students: 293	Technology: 94 Social Science: 68	Technology: 67 Social Science: 225	(specific by sex)	Technology: M=20.3 SD=1.1 Social Science: M=22.2 SD=3.5	Technology: M=19.8 SD=0.9 Social Science: M=22.0 SD=4.7	0.445	0.4717
Peters	2005	Sr	0.83	1765	501	1264	college undergrads	n/a	n/a	0.97	1.0647
Prizel & Freeman	1995	Sr	0.83	80	40	40	range: 18-30	n/a	n/a	0.84	0.9220
Quaiser-Pohletal	2006	Sr	0.87	861	356	505	M=14.67 SD=2.35 range: 10-20	n/a	n/a	0.63	0.6754
Rahman et al.	2005	Sr	0.83	52	26	26	range: 18-45	M=25.54 SD=5.40	M=26.69 SD=6.73	1.35	1.4818
Saucier et al.	2002	Sr	0.9	95	41	54	M=22.8 SD=5.44	n/a	n/a	0.9	0.9487
Silverman et al.	2000	Sr	0.83	186	81	105	(specific by sex)	M=22.24 SD=0.54	M=21.58 SD=0.40	0.982	1.0779
Stericker & LaVesconte	1982	Sr	0.83	83	38	45	college aged students	n/a	n/a	0.09	0.0988
Voyer & Hou	2006	Sr	0.83	203	100	103	range: 17-44 M=19.95 SD=3.82	n/a	n/a	0.86	0.9440
Weiss et al.	2003	Sr	0.83	97	46	51	college aged students	n/a	n/a	0.41	0.4500
Malinoski & Gillespie	2001	Ss	0.73	978	846	132	M=19.7	n/a	n/a	0.8	0.9363

		Ss	0.73	211	142	68	college aged students	n/a	n/a	0.8	0.9363
Silverman et al.	2000	Ss	0.73	186	81	105	(specific by sex)	M=22.24 SD=0.54	M=21.58 SD=0.40	0.982	1.1493
Choi & L'Hirondelle	2005	Vm	0.76	111	50	61	(specific by sex)	M=19.43 SD=0.15	M=19.17 SD=0.16	1.68	1.9271
Choi & Silverman	2003	Vm	0.76	290	144	146	range: 9-13	n/a	n/a	0.338	0.3877
Choi & Silverman	2003	Vm	0.76	290	144	146	range: 9-13	n/a	n/a	0.2	0.2294
Ecuyer-Dab & Robert	2004	Vm	0.76	216	95	121	(specific by sex)	M=34.3 SD=6.2	M=34.2 SD=6.1	0.0162	0.0186
Rahman et al.	2005	Vm	0.76	52	26	26	range: 18-45	M=25.54 SD=5.40	M=26.69 SD=6.73	0.65	0.7456
Alexander	2005	Vm	0.76	120	60	60	M = 20.4+/-1.9 range: 18-35	n/a	n/a	0.77	0.8833
Amponsah	1997	Vz	0.54	417	288	229	M=26.5 range:18-40	M=8.53 SD=2.90	M=8.91 SD=3.07	-0.06	-0.0816
Amponsah	1997	Vz	0.67	417	288	229	M=26.5 range:18-40	M=12.90 SD=2.85	M=12.19 SD=3.30	0.1	0.1222
Contreras et al.	2001	Vz	0.72	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.23	0.2711
Contreras et al.	2001	Vz	0.72	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.18	0.2121
Contreras et al.	2001	Vz	0.841	602	302	300	(specific by sex)	M=28.41 SD=4.15	M=27.14 SD=3.49	0.74	0.8069
Crucian & Berenbaum	1996	Vz	0.9	218	86	132	range: 18-46	M=20.0 SD=2.6	M=20.1 SD=4.3	0.41	0.4322
Lawton & Hatcher	2005	vz	0.76	281	72	209	(specific by sex)	M=22.85 SD=7.20 range: 18-54	M=22.95 SD=7.55 range: 18-51	-0.01647	-0.0189
Lachance & Mazzoco	2006	Vz	0.76	923	448	475	children in longitudinal study (started in kindergarden lasted 4 years)	Kind: M=5.83 SD=0.35 1st: 6.83 SD=0.34 2nd: M=7.84 SD=0.35 3rd: M=8.73 SD=0.30	Kind: M=5.72 SD=0.33 1st: M=6.69 SD=0.30 2nd: M=7.69 SD=0.31 3rd: M=8.61 SD=0.32	0.3	0.3441

Nordvik & Amponsah	1998	Vz	0.75	technology: 161 social science students: 293	Technology: 94 Social Science: 68	Technology: 67 Social Science: 225	(specific by sex)	Technology: M=20.3 SD=1.1 Social Science: M=22.2 SD=3.5	Technology: M=19.8 SD=0.9 Social Science: M=22.0 SD=4.7	0.36	0.4157
Stericker & LaVesconte	1982	Vz	0.76	83	38	45	college aged students	n/a	n/a	0.06	0.0688
Weiss et al.	2003	Vz	0.76	97	46	51	college aged students	n/a	n/a	0.18	0.2065

Discussion

I started this thesis with a historical review of the process of defining spatial ability, which has occurred through a transition of three phases; past research has helped understanding og a human ability that was once identified as being the same as visual, perceptual, and non-verbal reasoning abilities. Next, I reviewed research that was based on making conclusions/assumptions about gender differences in spatial abilities from single tests of spatial abilities that involved only one factor. After reviewing past literature regarding gender differences in spatial ability, I highlighted 10 specific spatial subdivisions which provided a taxonomy, or classification, for the different spatial sub-factors. Then I provided a step-by-step explanation of the statistical procedures used throughout the development of the meta-analysis, and finally, I reported that males demonstrate greater spatial abilities than females across all of the domains that comprise spatial ability.

Interpretation of Results: Although all of the effect sizes reveal that men outperform women in each of the spatial factors, it is clear that the degree of performance differences varies significantly across the different spatial factors. For example, with an effect size of 0.1558, differentiation between males and females is not as large for tests of Perceptual Speed as the performance differentiation found for test of Spatial Scanning, with an effect size of 0.965. This means that while males are significantly better than females in tests of Spatial Scanning, the difference in male and female abilities is minimal in tests of Spatial Scanning.

Four spatial factors showed less differentiation in male and female abilities. These subgroups included Perceptual Speed (d = 0.1558), Closure of Speed (d=0.174), Flexibility of Closure (*d*=0.231), and Visual Memory (*d*=0.3017). Perhaps, because the performance of males and females in these four factors shows less of a difference in ability, an underlying factor within these factors exists which helps to facilitate the performance of females. In other words, each of these tests might contain some similar content that women excel in. If researchers are able to find this component then the criteria associated with the different spatial factors could be changed and a new categorization for spatial abilities could be established.

It should also be noted that several of the factors men significantly outperformed women in require participants to mentally manipulate objects. Speeded Rotation requires examinees to determine whether an object is a rotated version of the target object or is a rotated and reflected version of the target object. Kinesthetic requires participants to make rapid left-right object discriminations. And Spatial Orientation requires subjects to determine how an object will appear when viewed from a new or different perspective. All three of the factors, for which men substantially outperformed women, involve the participant mentally manipulating objects, thus perhaps the task of mental manipulation might hinder female performance. The facts that show less gender differentiation do not require examinees to perform mental manipulations of objects. For example, Perceptual Speed involves matching visual stimuli, and Closure Speed requires participants to quickly identify incomplete or distorted pictures. Although these tests are clearly spatially related, the absence of mental manipulation might help females to execute the spatial tests.

Implications. Although I find it difficult to report such findings, I think the result of this meta-analysis has many important implications. Hopefully, future researchers may be able to use this knowledge of gender differences in spatial abilities to better predict or eliminate sex differences and develop strategies for increasing performance on spatial ability tasks. Now that the magnitude and nature of the gender difference has been established for all factors which encompass spatial ability, it is up to future researchers to study ways in which this gender difference can be reduced. For example questions such as how will test practice affect gender differences in spatial abilities need to be asked and then researched.

Another important area of study is concerned with the affect of hormone levels on spatial ability; researchers are currently trying to decide if the hormone androgen has positive influences on a person's ability to perform spatial tests (Anders & Hampson, 2005). This groundbreaking work is looking at the spatial performance of females with elevated androgen levels compared to the spatial performance of females with normal androgen levels. Studies of this nature are using homosexual female participants as well as females who are strongly engaged in rigorous sports (Cohen, 2002).

The results of this research can also have important implications involving the ability to predict success in occupations and academia. With the knowledge that males demonstrate greater spatial abilities than females across all domains that comprise the ability, teachers and employers should now be able to use this information to better understand and predict the success and struggles of their employees/students. I feel the strongest implication this study could make is for school systems and parents to realize that a gender difference does exist and to encourage training and exposure to spatial activities. Hopefully parents and childcare professionals will begin exposing their female children to spatial activities at a much earlier age. Teachers can use this information when covering topics such as geometry to better educate women students through harder work and practice than their male pupils. Perhaps this special attention to spatial tasks will even help their female students overcome the gender differences found in mathematical abilities. Employers can also use this information to better train their female employees who are required to complete tasks that involve spatial skills.

Limitations. Possible limitations of this study are based on the notion that the results of this investigation are only as good as the articles used within the meta-analysis. Although I feel confident in the quality of research selected for inclusion within this study, the statistics of this study are only as good as the statistics of the studies used for analysis. Another potential area of limitation involves the inclusion criteria. Perhaps results would have differed if a different set of inclusion criterion was established.

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